Table A3. Descriptive statistics for health inspection samples.

Sample I = All health inspections (N=63,383).

Sample II = All health inspections with worker exposure measures (N=26,386).

Name	Description	I Mean (std. dev.)	II Mean (std. dev.)
NUMBAD	Number of worker exposure samples in violation of relevant permissible exposure limit	---	1.486 (3.390)
NUMCITE	Number of citations on this inspection (includes health and safety citations).	2.475 (4.962)	3.433 (5.833)
SIC2	SIC code (2-digit).	31.3 (5.0)	31.2 (5.0)
SSEQNUM	Sequence number of safety inspections of this establishment (Dummy variables).		
SSEQNUM1	=1 if [Sequence number ≥ 1]	.684	.717
SSEQNUM2	≥ 2]	.459	.457
SSEQNUM3	≥ 3]	.298	.282
SSEQNUM4	≥ 4]	.197	.180
SSEQNUM5	≥ 5]	.134	.120
SSEQNUMC	Continuous variable: =SEQNUM-5 if SEQNUM>5; =0 otherwise.	.598 (3.555)	.486 (3.064)
SNINSP	Number of safety inspections of this establishment (Dummy variables)		
SNINSP1	=1 if [Safety inspections ≥ 1]	.168	.162
SNINSP2	≥ 2]	.159	.164
SNINSP3	≥ 3]	.128	.138
SNINSP4	≥ 4]	.097	.104
SNINSP5	≥ 5]	.264	.300
SNINSPC	Continuous variable: =NINSP-5 if NINSP>5 =0 otherwise.	1.260 (5.440)	1.375 (5.566)
HSEQNUM	Sequence number of health inspections of this establishment (Dummy variables)		
HSEQNUM1	=1 if [Sequence number ≥ 1]	1.000	1.000
HSEQNUM2	≥ 2]	.406	.357
HSEQNUM3	≥ 3]	.208	.175
HSEQNUM4	≥ 4]	.119	.093
HSEQNUM5	≥ 5]	.072	
HSEQNUMC	Continuous variable: =HSEQNUMC-5 if HSEQNUM>5 =0 otherwise	.157 (1.017)	.105 (.790)

Table A3. (continued).

Name	Description	I Mean (std. dev.)	II Mean (std. dev.)
HNINSP	Total number of health inspections of this establishment (Dummy variables)		
HNINSP1	=1 if [Total number ⩾ 1]	1.000	1.000
HNINSP2	⩾ 2]	.220	.224
HNINSP3	⩾ 3]	.127	.140
HNINSP4	⩾ 4]	.081	.088
HNINSP5	⩾ 5]	.178	.187
HNINSPC	Continuous variable: =HNINSP-5 if HNINSP>5 =0 otherwise.	.497 (1.960)	.497 (1.941)
HSEQNUM*HNINSP	Interactions between health inspection number and total health inspections		
HSEQ2*HNIN2	=1 if HSEQNUM=2 and HNINSP=2]	.110	.084
HSEQ2*HNIN3	HSEQNUM=2 and HNINSP=3]	.084	.075
HSEQ2*HNIN4	HSEQNUM=2 and HNINSP=4]	.061	.055
HSEQ2*HNIN5	HSEQNUM=2 and HNINSP=5]	.151	.142
HSEQ3*HNIN3	HSEQNUM=3 and HNINSP=3]	.042	.033
HSEQ3*HNIN4	HSEQNUM=3 and HNINSP=4]	.040	.033
HSEQ3*HNIN5	HSEQNUM=3 and HNINSP=5]	.125	.110
HSEQ4*HNIN4	HSEQNUM=4 and HNINSP=4]	.020	.015
HSEQ4*HNIN5	HSEQNUM=4 and HNINSP=5]	.099	.079
HSEQ5*HNIN5	HSEQNUM=5 and HNINSP=5]	.072	.054
ACCIDENT	=1 if [Origin of inspection = accident]	.008	.003
COMPLAINT	= complaint]	.398	.429
GENERAL	= general]	.424	.443
FOLLOWUP	= followup]	.170	.125
YR72	=1 if [Year of inspection = 72]	.010	.001
YR73	= 73]	.032	.046
YR74	= 74]	.046	.080
YR75	= 75]	.077	.120
YR76	= 76]	.085	.125
YR77	= 77]	.108	.135
YR78	= 78]	.114	.143
YR79	= 79]	.114	.099
YR80	= 80]	.126	.081
YR81	= 81]	.110	.069
YR82	= 82]	.112	.067
YR83	= 83]	.066	.033
ESTSIZE1	=1 if [Number of employees < 20]	.164	.128
ESTSIZE2	= 20-99]	.366	.360
ESTSIZE3	= 100-499]	.319	.351
ESTSIZE4	⩾ 500]	.152	.161

Table A4. Determinants of citations in health inspections.
Sample = All health samples (N=63,383).
Dependent variable = NUMCITE [mean=2.48, sd=4.96].
(Standard errors are in parentheses below coefficients)

	1A	1B	2A	2B
CONSTANT	2.99 (.09)	3.01 9.09)	2.83 (.16)	2.86 (.16)
Enforcement				
HSEQNUM2	-1.16 (.07)		-1.16 (.07)	
HSEQNUM3	- .33 (.09)		- .35 (.09)	
HSEQNUM4	- .12 (.09)		- .35 (.09)	
HSEQNUM5	- .01 (.13)		- .02 (.13)	
HSEQNUMC	-.09 (.03)	-.09 (.03)	- .09 (.03)	- .09 (.03)
HSEQ2*HNIN2		-1.30 (.04)		-1.27 (.09)
HSEQ2*HNIN3		- .95 (.14)		- .96 (.13)
HSEQ2*HNIN4		- .82 (.19)		- .85 (.19)
HSEQ2*HNIN5		-1.20 (.17)		-1.24 (.17)
HSEQ3*HNIN3		- .55 (.13)		- .54 (.13)
HSEQ3*HNIN4		- .45 (.19)		- .45 (.19)
HSEQ3*HNIN5		- .17 -(.17)		- .20 (.17)
HSEQ4*HNIN4		- .21 (.19)		- .20 (.19)
HSEQ4*HNIN5		- .18 (.17)		- .18 (.17)
HSEQ5*HNIN5		- .05 (.15)		.03 (.15)

Table A4. (continued).

	1A	1B	2A	2B
Enforcement (continued)				
SSEQNUM1	-1.48 (.07)	-1.48 (.07)	-1.39 (.07)	-1.39 (.07)
SSEQNUM2	- .21 (.07)	- .21 (.07)	- .17 (.07)	- .17 (.07)
SSEQNUM3	.11 (.08)	.11 (.08)	.11 (.08)	.11 (.08)
SSEQNUM4	- .11 (.10)	- .12 (.10)	- .09 (.10)	- .09 (.10)
SSEQNUM5	- .15 (.10)	- .15 (.10)	- .15 (.10)	- .14 (.10)
SSEQNUMC	.024 (.013)	.022 (.013)	.025 (.013)	.023 (.014)
<u>Plant Enforcement Controls</u>				
HNINSP2	1.17 (.06)	1.25 (.07)	1.16 (.06)	1.22 (.07)
HNINSP3	1.69 (.08)	1.63 (.10)	1.67 (.08)	1.61 (.10)
HNINSP4	1.84 (.09)	1.68 (.14)	1.85 (.10)	1.69 (.14)
HNINSP5	2.01 (.10)	1.98 (.13)	2.00 (.10)	2.01 (.13)
HNINSPC	- .009 (.019)	- .01 (.02)	- .001 (.019)	- .004 (.019)
SNINSP1	.92 (.08)	.92 (.08)	.77 (.08)	.78 (.08)
SNINSP2	1.06 (.09)	1.06 (.09)	.85 (.09)	.85 (.09)
SNINSP3	1.17 (.10)	1.17 (.10)	.93 (.10)	.93 (.10)
SNINSP4	1.14 (.11)	1.14 (.11)	.90 (.11)	.90 (.11)
SNINSP5	1.14 (.11)	1.14 (.11)	.86 (.11)	.86 (.11)
SNINSPC	-.001 (.009)	-.001 (.009)	-.013 (.009)	-.012 (.009)

Table A4. (continued).

	1A	1B	2A	2B
Inspection Controls				
ACCIDENT	- .24	- .25	- .03	- .04
	(.22)	(.22)	(.21)	(.21)
COMPLAINT	- .36	- .36	- .30	- .30
	(.05)	(.05)	(.05)	(.05)
FOLLOWUP	-2.05	-2.05	-2.09	-2.09
	(.07)	(.07)	(.07)	(.07)
YR72	- .24	- .26	- .37	- .38
	(.21)	(.21)	(.22)	(.22)
YR73	- .95	- .97	- .99	-1.00
	(.14)	(.14)	(.14)	(.14)
YR74	- .51	- .53	- .37	- .39
	(.12)	(.12)	(.12)	(.12)
YR75	.29	.27	.42	.40
	(.11)	(.11)	(.11)	(.11)
YR76	- .33	- .35	- .15	- .17
	(.10)	(.11)	(.10)	(.11)
YR77	- .70	- .73	- .53	- .56
	(.10)	(.10)	(.10)	(.10)
YR78	- .39	- .43	- .23	- .25
	(.10)	(.10)	(.10)	(.10)
YR79	- .16	- .19	.002	- .029
	(.10)	(.10)	(.097)	(.098)
YR80	.07	.05	.21	.19
	(.09)	(.10)	(.09)	(.10)
YR81	- .29	- .31	- .21	- .22
	(.10)	(.10)	(.09)	(.09)
YR82	.16	.16	.22	.22
	(.09)	(.09)	(.09)	(.09)
Plant Controls				
ESTSIZE1			.09	.09
			(.08)	(.08)
ESTSIZE2			.33	.32
			(.07)	(.07)
ESTSIZE3			.15	.15
			(.07)	(.07)
SIC2	No	No	Yes	Yes
R^2 (corrected)	.055	.055	.065	.065

Table A5. Determinants of number of samples violating exposure standards in health inspections.

Sample = All health inspections with samples (N=26,386).

Dependent variable = NUMBAD [mean=1.49, sd=3.39].

(Standard errors are in parentheses below coefficients)

	1A	1B	2A	2B
CONSTANT	1.93 (.12)	1.93 (.12	2.69 (.12)	2.69 (.19)
Enforcement				
HSEQNUM2	- .38 (.07)		- .42 (.06)	
HSEQNUM3	- .12 (.09)		- .13 (.09)	
HSEQNUM4	- .15 (.13)		- .13 (.13)	
HSEQNUM5	- .12 (.15)		- .06 (.15)	
HSEQNUMC	- .01 (.04)	- .01 (.04)	- .01 (.04)	- .01 (.04)
HSEQ2*HNIN2		- .38 (.09)		- .42 (.09)
HSEQ2*HNIN3		- .32 (.13)		- .38 (.13)
HSEQ2*HNIN4		- .38 (.10)		- .44 (.17)
HSEQ2*HNIN5		- .44 (.15)		- .48 (.15)
HSEQ3*HNIN3		- .40 (.15)		- .37 (.15)
HSEQ3*HNIN4		- .15 (.20)		- .17 (.20)
HSEQ3*HNIN5		- .02 (.16)		- .03 (.16)
HSEQ4*HNIN4		- .31 (.23)		- .28 (.22)
HSEQ4*HNIN5		- .26 (.17)		- .22 (.17)
HSEQ5*HNIN5		- .15 (.17)		.10 (.16)

Table A5. (continued).

	1A	1B	2A	2B
Enforcement (continued)				
SSEQNUM1	-.04 (.07)	-.04 (.07)	-.02 (.07)	-.02 (.06)
SSEQNUM2	.14 (.07)	.14 (.07)	-.11 (.07)	-.33 (.07)
SSEQNUM3	.13 (.08)	.13 (.08)	.13 (.08)	.13 (.08)
SSEQNUM4	.03 (.11)	.03 (.11)	.07 (.10)	.07 (.10)
SSEQNUM5	-.14 (.11)	-.14 (.11)	-.19 (.11)	-.19 (.11)
SSEQNUMC	.026 (.014)	.030 (.014)	.031 (.014)	.033 (.014)
<u>Plant Enforcement Controls</u>				
HNINSP2	.54 (.06)	.54 (.06)	.47 (.06)	.47 (.06)
HNINSP3	.91 (.07)	.94 (.09)	.75 (.07)	.78 (.09)
HNINSP4	.99 (.09)	.91 (.12)	.83 (.09)	.75 (.12)
HNINSP5	1.39 (.09)	1.39 (.11)	1.12 (.09)	1.14 (.11)
HNINSPC	-.03 (.02)	-.028 (.019)	-.017 (.018)	-.015 (.018)
SNINSP1	.17 (.09)	.19 (.09)	.03 (.08)	.03 (.08)
SNINSP2	.35 (.09)	.35 (.09)	.11 (.09)	.11 (.09)
SNINSP3	.40 (.10)	.39 (.10)	.08 (.10	.08 (.10)
SNINSP4	.50 (.11)	.50 (.11)	.12 (.11)	.12 (.11)
SNINSP5	.71 (.10)	.71 (.11)	.21 (.11)	.21 (.11)
SNINSPC	-.003 (.008)	-.004 (.008)	-.027 (.008)	-.027 (.008)

Table A5. (continued).

	1A	1B	2A	2B
Inspection Controls				
ACCIDENT	- .54	- .54	- .55	- .56
	(.36)	(.36)	(.35)	(.35)
COMPLAINT	- .69	- .69	- .65	- .66
	(.05)	(.05)	(.05)	(.05)
FOLLOWUP	- .17	- .17	- .31	- .32
	(.07)	(.07)	(.07)	(.07)
YR72	.13	.12	- .47	- .48
	(.55)	(.55)	(.54)	(.54)
YR73	- .96	- .97	-1.16	-1.17
	(.15)	(.15)	(.15)	(.15)
YR74	-1.44	-1.45	-1.43	1.44
	(.14)	(.14)	(.14)	(.14)
YR75	-1.43	-1.44	-1.37	-1.38
	(.13)	(.13)	(.13)	(.13)
YR76	-1.50	-1.51	-1.35	-1.36
	(.13)	(.13)	(.13)	(.13)
YR77	-1.38	-1.39	-1.27	-1.28
	(.13)	(.13)	(.13)	(.13)
YR78	-1.33	-1.34	-1.22	-1.23
	(.13)	(.13)	(.13)	(.13)
YR79	- .34	- .35	- .23	- .24
	(.13)	(.13)	(.13)	(.13)
YR80	.23	.22	.29	.29
	(.13)	(.13)	(.13)	(.13)
YR81	.17	.16	.20	.19
	(.14)	(.14)	(.13)	(.13)
YR82	.24	.24	.24	.24
	(.14)	(.14)	(.13)	(.13)
Plant Controls				
ESTSIZE1			-1.17	-1.16
			(.09)	(.09)
ESTSIZE2			- .81	- .81
			(.07)	(.07)
ESTSIZE3			- .31	- .31
			(.07)	(.07)
SIC2	No	No	Yes	Yes
R^2 (adjusted)	.062	.062	.102	.102

HITTING THE "T": THE REGULATORY LOSS OF SOIL MANAGEMENT POLICY*

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PRELIMINARY

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Hitting the "T":

The Regulatory Loss of Soil Management Policy

ABSTRACT

The federal government has in its active role of encouraging soil conservation taken as a goal the "T", or tolerance level, of the soil being managed. However, the success of the hitting the "T" has been limited. This paper explains the basic framework of a dynamic regulatory "game" between the government and the farmers it is trying to influence, and explores how the way farmers react to interventionist activities may be responsible for the limited success in encouraging soil conservation. Within this framework new techniques for formulating effective policies are explored, and an empirical application to Maine potato farmers is performed.

I. Introduction

The federal government, primarily through the Soil Conservation Service (SCS) and the Agricultural Conservation Program (ACP)[1], has long been an active participant in the conservation of soil resources. Its programs have tried to encourage farmers to increase the soil management that they practice. The involvement of the government has focused on the goal of the "T", or tolerance level of the soil being managed. The "T" is that rate of erosion which does not affect the long term productivity of the soil. Economists have argued long and hard that the "T" is not the proper level of soil management from a welfare analysis perspective.[2] However, our ability to influence policymakers has been limited. Thus, since the political process has evolved to the goal of "T" level of erosion, it may be interpreted in some sense as a regulatory objective. As with any goal, the policymakers face tradeoffs with budgetary considerations and other programs in meeting this objective.

Within this constraint there are optimal and suboptimal ways of formulating a policy intervention to move farmers towards the objective of "T" erosion. The difference comes from how the policymaker interacts with the farmers. Because of the dynamic elements in a soil management decision, the policymakers (essentially the SCS and ACP) play a dynamic game with the farmers, and how the farmers respond limits the effectiveness of policy rules. (This point was made clear in Lucas's (1976) critique of econometric policy evaluation). For the policymakers, this means any rule changes the future expectations farmers formulate, and thus they may not respond as expected. Upon reevaluating the policy, a new rule will be established. As the process converges, the policy rule may evolve to a time consistent one upon which the policymaker cannot gain by revising.

However, Whiteman (1986) shows that a rule which dominates the time consistent one is a precommitment[3] strategy: at the beginning of the "game" the policymaker sets a rule and promises never to change it. For this rule he exploits the fact that expectations respond to the rule, and maximizes his objective (in this case hitting the "T") subject to that constraint. The contention of this paper is that the ASCS (with its ACP) followed the former policy (in pursuit of short term gains), evolving to a time consistent rule, which resulted in a larger deviation from the "T" than if the optimal precommitment strategy had been followed. That is, in formulating policies for soil management subsidization the ASCS neglected the effects its own decisions have on farmers expectations of future soil management decisions. This paper argues that these effects are important and thus the government should have viewed the policy problem as a game against intelligent agents.

Many researchers have recognized the impotence of soil conservation policies and have tried to analyze reasons why. However, most studies have been suggestive or discursive rather than analytical. Batie (1982), for example, reviews policies that support and encourage soil conservation, with a discussion of how different policies both help and hurt. Similarly, Easter and Cotner (1982) conclude that current policies are ineffective, but also add that the data needed to evaluate the strategies are not available.

A more analytical study was done by Forster and Becker (1979). It contrasts three alternative policies; restrictions on soil loss, taxes on soil loss, and subsidies for erosion control. In an application to the Lake Erie watershed basin, the different policies are shown to have nearly the same net economic benefits, although the distribution of these benefits differ.

Given the ineffectiveness of current policies, many researchers have concluded that we need a better idea of why farmers adopt (or don't adopt) soil management practices. For example, Napier, et al (1984, p.205), argue that since current policies are ineffective "... new mechanisms must be developed. Farmers must be motivated to adopt conservation practices without 'bribing' them with monetary incentives or 'forcing' them to correct the problem." They conclude that our focus as researchers should be to identify factors that help predict why farmers choose soil conservation practices.[4]

This paper takes an alternative view. Rather than try to explain why farmers adopt soil management practices, and then design new programs to exploit that understanding, I follow the lead of Moore, et al (1979) and Prato (1987). These papers looks at current programs which share the cost of soil management and analyze how they can be reorganized to make soil management practices financially attractive to farmers (Moore) or more effective (Prato). Herein is the problem which is the focus of this paper. How to take an (existing) policy (in my particular application the ACP) and make it more effective in achieving its goals.

To relate this point to the earlier discussion of optimal and consistent plans, a very brief description of the ACP would be useful.[5] The ACP is a cost sharing program for the adoption of soil conservation practices. Although until 1978 there was a cap of $2,500.00 per individual per year, there has always been considerable leeway in cost share rates and eligibility. They are determined at the county level by farmer representatives (within federal and state guidelines) and these representatives decide who receives funds. This discretion is not always beneficial. Rasmussen (1982) points out that much of the ACP dollars spent prior to 1980 went for production-oriented practices rather than more focused soil conservation. My contention is that much of the failing in the ACP may be due to the discretionary orientation of the program. While this may make it more attractive to farmers in the onset, in the long run the dynamic interaction leads to policy ineffectiveness.

The remainder of this paper is organized as follows. In section II the problem facing the policymaker is explained within the constructs of a simple model of farmer decision making. A solution to the farmers' problem under rational expectations is characterized and the policymaker's problem is solved. Section III is an application to Maine potato farmers. and the actual policy values are compared to the optimal ones. Section IV provides some concluding statements. There are three appendices to this paper. The first contains some mathematical derivations used at points in the analysis, the second is the proof of proposition 2, and the third is a short discussion of the data on Maine potato farmers that is used in the application.

II. Soil Management Policy and the Dynamic Game

The SCS and ASCS have used as a goal for soil policy to hit the "T", that is the tolerance level of erosion that the soil can support. This is a "steady state" concept that maintains the soil depth and its long-term productivity.[6] In the soils literature soil loss is usually measured in tons per acre, as given by the Universal Soil Loss Equation (USLE).[7] The USLE is given by $T = CxPxRxKxLxS$ where T is the long-term soil loss (in tons per acre)[8], C and P are measures of cultivation and rotation practices, and the remaining parameters measure the inherent characteristics of the soil at risk, which are essentially beyond the control of the farmer. Heimlich and Bills suggest dividing the USLE into two parts, the soil management measure (CP) and the soil constraints measure (RKLS), which will be termed potential erosion here.

It is now possible to state the policymakers' problem: At each point in time the farmers choose soil management (essentially the CP factors of the USLE) which determines the soil loss when combined with the potential erosion. The policymaker wants to influence the farmer so that the choice of soil management results in a soil loss equal to the tolerance level of the field. Let T* be the tolerance level of the field in question. Then, letting potential erosion (POT) be constant through time, the actual soil loss at time t is

$$T_t = M_t POT \tag{1}$$

where M_t is the soil management choice (the CP factors of the USLE) the farmer makes. The policymaker wants $T_t=T*$, or equivalently, $M_t=M*=T*/POT$. The policymaker tries to alter the farmer's behavior by providing a subsidy, S_t, per unit of M_t practiced. However, the program faces a budget constraint. Therefore, the objective is to hit the T while keeping the variance from the budget to a minimum. If the budgeted amount for soil conservation policies is $S*_t$, an expression which captures the policymaker's objective is to minimize

$$E\{(M_t-M*)^2 + h(S_t-S*_t)^2\} \tag{2}$$

where E is expectations and h is a nonnegative parameter.

Farmers face the problem of choosing soil management practices and inputs to maximize profits. Inputs combine with soil to produce the crop, and the marginal productivity of each is affected by soil management. The primary soil management technique used in this study is crop rotation, so it is the previous year's soil management that effects this year's yield. Thus, the farmer's output, Y_t, is given by

$$Y_t = f(X_t,\ D_t,\ M_{t-1}) \tag{3}$$

where X_t are the inputs used, D_t is the soil depth, M_{t-1} is the previous year's soil management and $f(.,.,.)$ is the production function.[9]

The farmer chooses X and M to maximize the present value of future profits

$$E_{-1}\sum_{t=0}^{\infty} b^t\{Y_t - R_{t-1}X_t + S_{t-1}M_t\} \tag{4}$$

where E_j is conditional expectations at time j, R_t is the real price of inputs (the price of the crop is used as a <u>numeraire</u>) and b is the farmer's rate of time preference (discount factor). Notice, in this specification the farmer purchases the inputs the period prior to there use and knows the subsidy amount prior to investing in soil management practices. Equation (4) assumes there is no direct cost of soil management practices. Since in the data used for our analysis the primary practice is crop rotation, we are implicitly assuming that the alternative crop is break-even in terms of cost and revenue.

The maximization is performed ignoring the fact that

(5) $$D_{t+1} = d_1D_t + d_2M_t$$

where d_1 and d_2 are positive parameters. This means farmers account for only the productivity effects of soil management, not the long term effects. We assume that the supply curve for inputs is perfectly elastic (horizontal) except for shocks, and farmers know that

(6) $$R_t = A*(L)u_t$$

where A*(L) is a square-summable polynomial in the lag operator (L) and u_t is fundamental for R_t, that is, u_t is the sequence of one-step-ahead forecast errors made from predicting R_t from its own past.

As shown in appendix A, the Euler equations for the farmer's problem can be solved for a decision rule for choosing soil management practices that follows the expectational difference equation

(7) $$E_tM_{t+1}-d_1E_{t-1}M_t-K_1d_2M_t = (1-d_1L)\{K_2E_tR_{t+1}+K_3S_{t+}K_0\}$$

where the K_i are parameters which are functions of the parameters of the production function. The policymaker seeks to set S_t according to the rule

(8) $$S_t = F*(L)u_t$$

where F*(L) is a polynomial in nonnegative powers of L so that the solution to (7) will minimize the value of the objective function. Whiteman (1986) shows the solution to the policymaker's problem when d_1=0. However, as we shall see, with feedback in the system (essentially from equation (5)) the solution to the policymaker's problem is somewhat more difficult.

Proposition 1: (Equilibrium Soil Management Rules). When the policymaker precommits to a rule for setting S_t by $S_t=F^*(L)u_t$, soil management practices followed by farmers will follow the path $M_t=C(L)u_t + C^*$ where

$$C^* = [(1-d_1)/(1-p)]K_o \tag{9a}$$

and

$$C(L) = \frac{(1-d_1L)\{LA(L) + LF(L) + C_o\}}{(1-pL)} \tag{9b}$$

where $p=d_1+K_1d_2$, $C_o=-p^{-1}\{A(p^{-1})+F(p^{-1})\}$, $A(L)=K_2L^{-1}[A^*(L)-A^*_o]$ and $F(L)=K_3F^*(L)$, as long as $|p|>1$.

Proof: Using Wiener-Kolmogorov prediction formulas $K_2E_tR_{t+1} = K_2L^{-1}\{A^*(L)-A^*_o\}u_t = A(L)u_t$. Similarly, supposing that $M_t = C(L)u_t + C^*$ gives that $E_tM_{t+1} = L^{-1}\{C(L)-C_o\}u_t + C^*$ and $E_{t-1}M_t = L\{E_tM_{t+1}\} = \{C(L)-C_o\}u_t + C^*$. By substitution, equation (7) may be written

$$\{L^{-1}[C(L)-C_o] - d_1[C(L)-C_o] - K_1d_2C(L)\}u_t + (1-d_1-K_1d_2)C^* = (1-d_1L)\{A(L) + F(L)\}u_t + (1-d_1)K_o. \tag{7'}$$

Let $d_1 + K_1d_2 = p$. Then equating coefficients of the polynomials in L from (7'), after some rearranging gives

$$C^* = [(1-d_1)/(1-p)]K_o$$

and

$$C(L) = \frac{(1-d_1L)\{LA(L) + LF(L) + C_o\}}{(1-pL)}.$$

As shown in Whiteman (1983, p.7), stationarity requires that

$$C_o = -p^{-1}\{A(p^{-1}) + F(p^{-1})\}.$$

This completes the proof.

The solution to the policymaker's problem is found by using (9a) and (9b) to calculate the variance of M_t around M* and (8) to compute the variance of S_t around $S*_t$, and then choosing F(L) to minimize expression (2). The methods are an adaptation of those given in Whiteman (1986). Here, it is necessary to formulate the rule within the feedback constraint imposed by (5). We seek the "open loop" form of the policy where policymakers react to the shocks, not the soil management rules. As long as we assume that the farmers behave as if they cannot influence the policy rules, the "closed loop" policies ($S_t = b(L)S_t + B(L)M_t$) offers no strategic advantage (although it may be easier for implementation, since the policymaker need see only the farmers soil management practices, not the shocks to the system). Additionally, under this assumption, the closed loop policy is easily derived from the open loop policy, (as is done in the application in section III).

The derivation of the optimal precommitment open loop policy rule follows the derivation of Theorem 1 in Whiteman (1986).

<u>Proposition 2:</u> (The Optimal Precommitment Soil Management

Policy Rule). Assume that a policy rule of the form (8) is to be employed to minimize the objective function given by (2), subject to the constraints (6) and (7). The z-transform of the coefficients F_0, F_1, ... in the optimal precommitment policy rule is given by

$$(10) \quad F(z) = \frac{(hp+d_1)^{-1}\{zd(z)d(z^{-1})A(z)-md(m)d(m^{-1})A(m)\}}{(1-mz)(1-m^{-1}z)}$$

where $d(z) = 1-d_1z$, $|m|<1$ comes from the factorization

$$g(1-mz)(1-mz^{-1}) = [h(1-pz)(1-pz^{-1}) + (1-d_1z)(1-d_1z^{-1})]$$

and $F*(z) = F(z)/K_3d_2$.[10]

<u>Proof:</u> This proof follows that of Whiteman's Theorem 1 (1986, p.1392). As in his proof we shift to the "frequency domain" using the inversion formula from the covariance generating function for M_t. However, the feedback in the soil transition equation makes this a nontrivial adaptation of Whiteman's proof. For expositional convenience, the details are given in Appendix B.

If h=0 (that is if the ASCS is concerned only with hitting the T) it is easily shown that $F(z)=-A(z)$.[11] Under such a circumstance the ASCS should react to changes in relative prices (that is, changes in R_t) with changes in the subsidy (S_t) to just offset the former and move the farmers to M*. In the more general case the optimal precommitment policy is

$$(11)\quad S_t = mS_{t-1} + (hp+d_1)^{-1}\,\frac{Ld(L)d(L^{-1})A(L)-md(m)d(m^{-1})A(m)}{1-m^{-1}L}\,u_t.$$

Substituting (10) into (9b) describes the path of soil management if policymakers follow this rule. When the soil management subsidy is set by the rule given by (11), soil management follows the path[12]

$$(12)\qquad M_t = \frac{(1-d_1L)[hp(1-p^{-1}L)(1-pL)][LA(L)-mA(m)]}{(1-pL)(hp-d_1)(1-mL)(1-m^{-1}L)}\,u_t$$

and the closed loop precommitment policy is given by

$$(13)\quad S_t = p^{-1}S_{t-1} + \frac{(1+d_1{}^2)}{hp(1-d_1L)}\,M_t - d_1\frac{(1+L^2)A(L)-(1+m^2)A(m)}{hp(1-d_1L)[LA(L)-mA(m)]}\,M_t.$$

An interesting difference between equation (13) and the closed loop precommitment policy derived by Whiteman in his generic case is persistance of past soil management on current policy. In fact, the entire history of soil management affects current policy. This is a consequence of the feedback from soil management into the state of the environment (that is, the fact that d_1 does not equal zero).[13] In the next section we derive this rule for subsidizing soil conservation (ACP grants) for Maine potato farmers.